



Foraging Behavior of Fishes in Aquatic Plants

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PURPOSE: Foraging behavior of juvenile bluegill (*Lepomis macrochirus*) and largemouth bass (*Micropterus salmoides*) was observed in aquatic plants using underwater videography. This note describes relationships between plant stem density and foraging of fish, and discusses application of these data to evaluate the habitat value of aquatic plant beds.

BACKGROUND: Small species of fish and juveniles of larger species occupy aquatic plant patches for food (Pardue 1973; Keast 1984) and protection from predators (Crowder and Cooper 1982; Savino and Stein 1989). Differences in density and morphology of plants influence foraging intensity and degree of predator avoidance (Dionne and Folt 1991; Lillie and Budd 1992; Wyckera et al. 1993; Dibble, Killgore, and Dick 1996), which in turn influence fish growth and survival. Foraging efficiency decreases in dense plant beds (Savino and Stein 1982; Anderson 1984), but plant architecture (e.g., interstitial space formed by the arrangement of stems and leaves) can mediate negative effects (Lynch and Johnson 1989; Lillie and Budd 1992; Johnson 1993). High-density plant beds, however, offer greater protection from predators than medium- or low-density beds (Hayse and Wissing 1996). These tradeoffs, between reduced foraging value and increased protection from predators, make assessments of optimal or threshold densities of aquatic plants difficult.

Behavioral studies of fish can be used to assess the functional value of plant densities, but such studies usually require direct observation. In plant beds, low turbidity allows observation of individual fish behaviors in structurally complex habitats. In this study, the effect of different plant stem densities on foraging strategies of fish in a Wisconsin lake was evaluated with underwater videography.

METHODS AND MATERIALS: This study was conducted at Devil's Lake, Baraboo, Wisconsin. The lake is clear, oligotrophic, and has shallow littoral areas consisting of mixed assemblages of native aquatic plants. Sampling efforts were concentrated along the southern and southwestern shores where aquatic plants were the most abundant and diverse.

Underwater Videography. An underwater video camera was used to record bluegill and largemouth bass distribution and behavior in aquatic plant patches of varying densities (herein called sites). Eight sites were recorded with video cameras in August 1995 and 22 sites were recorded in August 1996. Water depth among the sites ranged from 0.7 to 1.6 m. A JVC VHS-C video camera in a waterproof housing was mounted on a t-post and connected to a monitor positioned on the bank by a 30-m cable. When a plant site was randomly located, the camera was positioned and mounted into the sediment. The camera's field of vision was approximately 1.56 m². Suspended sediment was allowed to settle for 15-20 minutes, after which time fish activity was recorded for approximately 1 hr.

Aquatic Plant Measurements. Immediately after videotaping, stem density of each plant species was measured within a 0.09-m² quadrat placed 0.5 m in front of the camera. Plants were

uprooted and taken back to the bank, identified, and total stem density was enumerated (Pringle 1984). Values were reported as number/m². Stem density of individual plant species within a site was divided by total stem density to determine percent composition.

Behavioral Analysis. Fifteen video samples were analyzed for bluegill and largemouth bass distribution and foraging behavior. Fifteen random, 1-minute focal samples were taken from each video with the use of a Panasonic VG-1500 editing deck for a total of 3 hours and 45 minutes observation time. During each focal sample, frequency (total number of observations) and duration (in minutes and seconds) of visits of every bluegill and largemouth bass were recorded, as well as frequency and duration of foraging in the site. Foraging behavior included search and orientation (swim, stop, focus), chase (swimming bursts), strikes (open water), and gleaning (biting on plant).

Fish behavioral variables were compared among sites with different plant stem densities. Histograms were developed from frequency distributions and Habitat Suitability Index (HSI) curves were constructed from the histograms. HSI values, which range from 0 (no value) to 1 (maximum value), are used in the Habitat Evaluation Procedure to rate the quality of a particular habitat (U.S. Fish and Wildlife Service 1980). The y-axis (time) was normalized by dividing time spent in each class interval of plant densities into the maximum time recorded in any one class (i.e., HSI = 1.0). A curve was fitted to the distribution by drawing a line through the midpoint of each class interval. These and other line-fitting techniques for constructing HSI curves are discussed in Bovee (1986) and Bovee and Zuboy (1988).

RESULTS AND DISCUSSION

Aquatic Plant Species Composition. Total aquatic plant stem densities in the study area ranged from 344 to 1600 stems/m², with a mean (\pm SD) of 817 ± 399 . Stem densities ranged from low to moderately high values that naturally occur in vegetated water bodies, although aggressively growing species such as *Myriophyllum spicatum* can exceed 1,700 stems/m² (Lillie and Budd 1992). Only one monospecific plant site was sampled, which precluded analysis of species-specific effects on fish foraging; other sites consisted of two to five aquatic plant species.

The two most common aquatic plant species were *Potamogeton robbinsii* (Robbin's pondweed) and *Elodea canadensis* (Canadian elodea) (Figure 1). These species have contrasting growth forms. *P. robbinsii* has long, crowded alternate simple leaves that are linear to lanceolate; stems are smooth, branched, and can grow up to 0.60 m in length. *E. canadensis* is either rooted or free-floating (Aulbach-Smith and de Kozlowski 1996), and leaves are whorled, elliptic, and narrow. Species that were less common were *P. illinoensis* (Illinois pondweed), *Najas flexilis* (bushy pondweed), *Ceratophyllum demersum* (coontail), and *Vallisneria americana* (water celery).

Frequency and Duration of Fish Behavior. Juvenile bluegill were observed 1,069 times, and of these observations, 306 were of foraging (Table 1). The mean (\pm SD) total length (mm) of bluegill was 48 ± 10 mm. Frequency of visits ranged between 6 and 243, and frequency of foraging ranged between 0 and 47. Duration of visits by bluegill totaled 187 min, 45 sec, and duration of foraging totaled 68 min, 41 sec. Duration of visits ranged from 18 sec to 51 min, 39 sec. Duration of foraging ranged from 0 to 13 min, 37 sec.

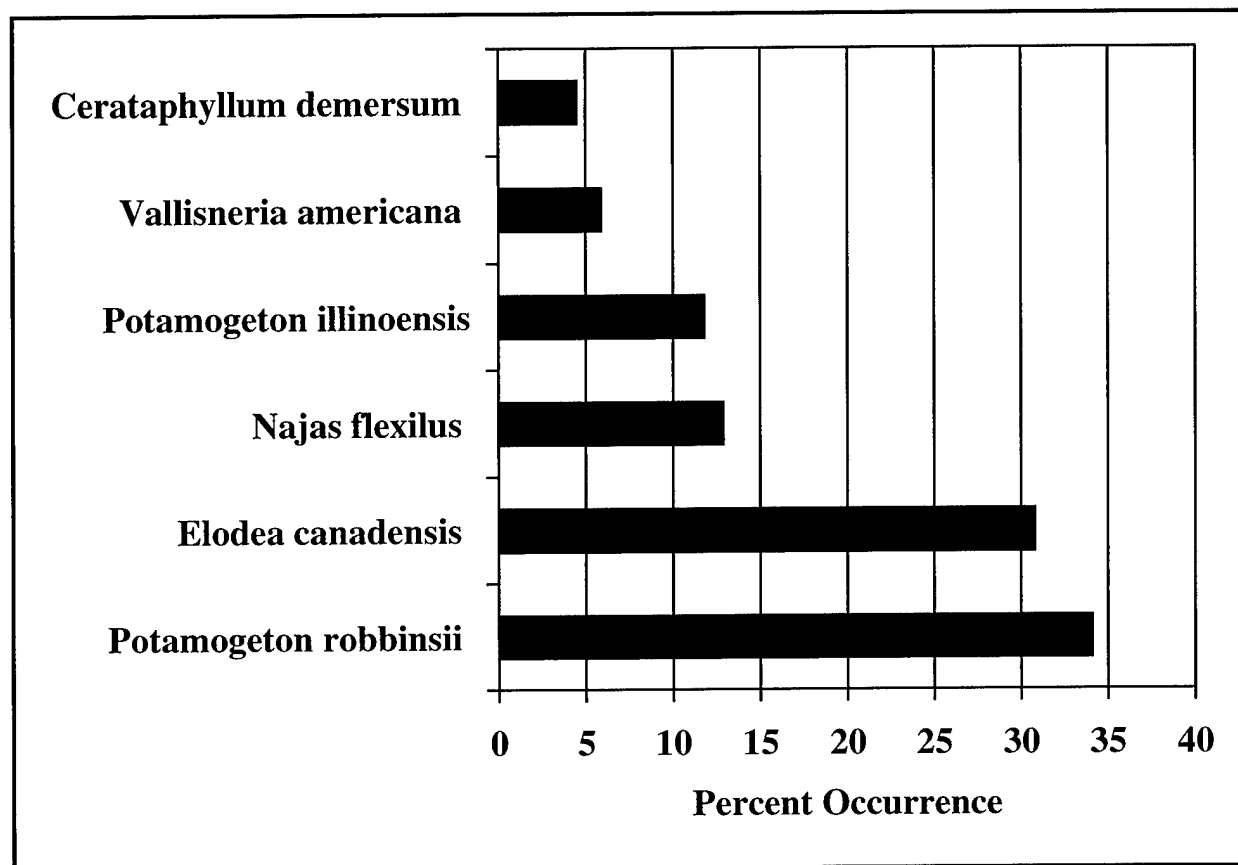


Figure 1. Percent occurrence of plant species in Devil's Lake, Wisconsin

Juvenile largemouth bass were observed 186 times, and of these observations, 25 were of foraging (Table 1). The mean (\pm SD) total length (mm) of largemouth bass was 169 ± 57 . Frequency of visits ranged from 0 to 30, and frequency of foraging ranged from 0 to 6. Duration of visits totaled 23 min, 24 sec, and duration of foraging totaled 6 min, 6 sec. Duration of visits ranged from 0 to 4 min, 27 sec. Duration of foraging ranged from 0 to 2 min, 4 sec.

Effect of Plant Stem Density. Foraging duration by juvenile bluegill was similar among sites of different stem densities, but total time (foraging and non-foraging) was greater in sites with intermediate to moderately high stem densities (Figure 2). In contrast, largemouth bass foraged more frequently and spent considerably more time in sites with low stem densities. However, largemouth bass tended to "cruise" through plants and occupy a patch for less than a minute, whereas bluegill resided in one location for a significantly ($p < 0.001$, ANOVA) greater period (Table 1).

An HSI curve was constructed to illustrate how these data can be used to evaluate habitat quality of mixed plant communities (Figure 2). Highest habitat value occurred at intermediate and low stem densities for bluegill and largemouth bass, respectively. In addition, the relationship between foraging and total time suggests that the primary function of plants may differ between fish species. For bluegill, the disproportionate use of intermediate stem densities, with no increase in foraging, suggests that cover is the primary function. Conversely, the relationship between foraging and total

Table 1
Frequency and Duration (in minutes:seconds) of Visits and Foraging in Aquatic Plants
by Juvenile Bluegill and Largemouth Bass

Bluegill					Largemouth bass			
Site	Visit Freq	Forage Freq	Visit Dur	Forage Dur	Visit Freq	Forage Freq	Visit Dur	Forage Dur
1	56	23	7:13	3:52	9	2	1:03	0:13
2	36	13	6:19	4:14	27	5	4:27	2:04
3	6	1	1:04	0:30	30	1	3:01	0:11
4	30	10	13:35	3:08	7	0	0:21	0
5	80	34	19:56	11:45	8	0	0:31	0
6	103	42	15:07	7:34	14	2	2:23	0:54
7	110	47	26:52	13:37	23	6	3:48	1:28
8	19	1	1:08	0:09	7	0	0:49	0
9	70	16	5:07	1:58	6	2	0:56	0:14
10	165	41	15:35	4:55	15	0	0:43	0
11	8	0	0:18	0	11	0	1:06	0
12	243	34	51:39	5:44	9	0	1:48	0
13	41	11	5:24	2:17	6	1	0:23	0:06
14	49	14	8:37	3:40	0	0	0	0
15	53	19	9:51	5:18	14	6	2:05	0:56
Total	1069	306	187:45	68:41	186	25	23:24	6:06

time in plants by largemouth bass was similar among stem densities, indicating plant beds are primarily being used as feeding areas.

Studies have suggested that juvenile bluegills select higher vegetation densities to reduce predation, and that an increase in invertebrate abundance with increasing vegetation density allows increased encounter rates, offsetting decreased capture rates (Savino and Stein 1982; Gotceitas and Colgan 1987; Hayse and Wissing 1996). The current study supports these conclusions, and quantifies duration of fish activities as a function of plant stem density. Behavior by largemouth bass may be regulated by similar factors, except that this species prefers to wait at the periphery of plant beds or in less-structured areas during non-foraging periods.

MANAGEMENT IMPLICATIONS: Foraging rates decline as macrophyte density increases (Crowder and Cooper 1982; Savino and Stein 1982; Gotceitas 1990), but prey are abundant in densely vegetated areas (Hayse and Wissing 1996). As a result, rates of prey consumption may not decline in dense vegetation. In this study, fish spent only 30-40 percent of the time foraging, and duration of foraging among sites with different plant stem densities did not differ as much as total

time. This indicates that overall residence time in vegetation is a more sensitive predictor of habitat value than just foraging time.

Juvenile bluegill prefer intermediate to moderately dense vegetation, and based on HSI values derived in this study, stem densities of approximately 1,200 stems/m² would provide optimum habitat. Conversely, largemouth bass prefer to wait at the periphery of plant beds or in areas of lower plant densities (300 stems/m²). The habitat value of littoral vegetation can be rapidly assessed and monitored using standardized values, such as HSI's, and tradeoffs among fish species can be determined for plant control or fishery management actions. Although this level of evaluation does not include other factors that can directly influence fish behavior, such as water quality, it does indicate that dispersion of vegetation patches is important when managing the structural landscape of littoral zones. Ideally, moderately dense patches of vegetation surrounded by sparsely distributed plants will provide optimum habitat for most sunfishes.

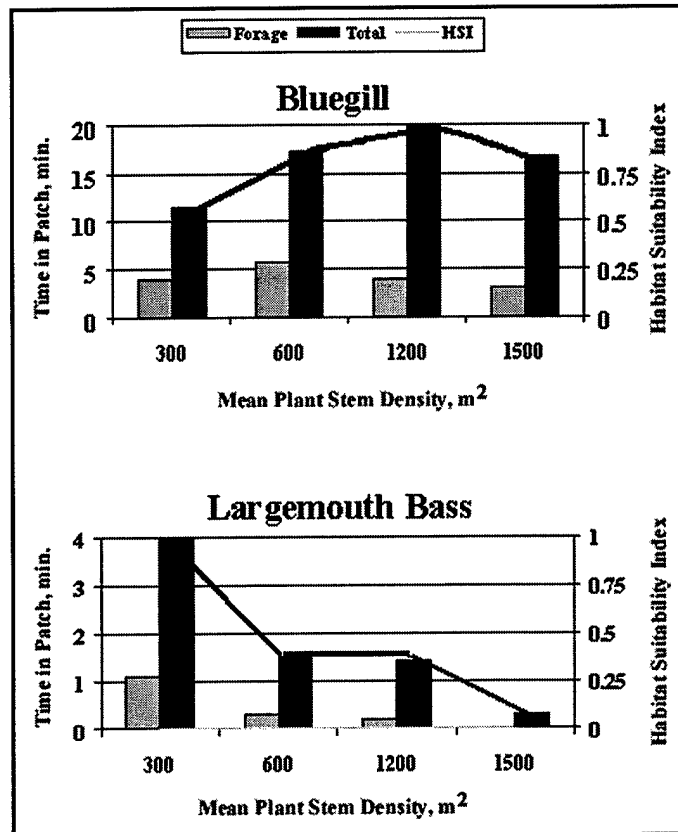


Figure 2. Foraging and total time in aquatic plants over a range of stem densities in Devil's Lake, Wisconsin for juvenile bluegill and largemouth bass. Habitat Suitability Index values refer to total time in patch, and range from 0 (no habitat value) to 1.0 (optimum habitat value)

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